Global Positioning System Selective Availability: Legal, Economic, and Moral Considerations

A Monograph
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ABSTRACT

GLOBAL POSITIONING SYSTEM SELECTIVE AVAILABILITY; LEGAL, AND MORAL CONSIDERATIONS by Major Jeffrey K. McGee, USA, 53 pages.

Since World War II, the United States has yielded many of its policy decisions to the desires of the United States military. These policy decisions reach from nylon and aluminum restrictions for the war efforts of World War II through the tough military build-up policies of the 1980s amidst fiscal constraints. In the aftermath of the conflict in Vietnam, President Ronald Reagan was determined to regain America's influence in the world by rebuilding the military and strengthening the economy. In 1989, the Berlin Wall came crashing down as the prelude to the fall of the Soviet Union and the Iron Curtain of communism.

Without the apparent threat of war with the Soviet Union, the United States began to focus more on maintaining an economic and political leadership role around the world. No longer did the United States military hold a firm grip on the rudder of national policy. Instead, a balance between the amount of military power required to remain relevant in the world and economic and political influence was sought.

One of the tools provided by the military to the civilian community is the Global Positioning System (GPS). This system, originally designed for the United States military, was released for public use in a degraded form after the tragic downing of a Korean airliner by Soviet fighter aircraft after the airliner unknowingly strayed into Soviet airspace in 1983. The GPS system's full accuracy capability was not released to the public out of fear by the Department of Defense (DOD) that potential adversaries might use the system for inertial guidance of smart munitions against the U.S.

Currently, there is a controversy over the possibility of expanded access to the highly accurate GPS signals heretofore available only to authorized DOD users. The decision to grant full access to the precision signal will be made by the President of the United States after weighing all of the factors which impact on the full release of this system for unrestricted civilian use.

Use of the GPS around the world has grown dramatically since public access to degraded signals was granted in 1983. Realizing the vast potential of this system, allied militaries, civil aviation, maritime industries, and private individuals have purchased the GPS receivers to improve their positional awareness for a variety of commercial and recreational uses.

The intent of this monograph is to explore the legal, moral, and economic factors that influence the presidential decision making process. The author uses the impending decision on granting full access to the GPS system to everyone worldwide as a case study of the dynamics of presidential decision making in seemingly military issues. Exploring the multiple factors that will influence an executive decision will provide the reader with a better understanding of the complexities involved in a single decision at the presidential level.

The study concludes that the decision by the president will impact the nation legally, economically, and morally. By increasing access to the GPS signals, the U.S. will have provided the required navigational devices for transit within the confines of its territory. The decision to increase civil access to the GPS signals will increase the number of civil applications available for GPS. An increase in applications will result in more production, lower prices, and increased demand for GPS products. Increased sales mean more prosperity for U.S. corporations and the U.S. economy. Morally, with increased GPS access, the president will provide greater safety for U.S. citizens, as well as all travelers onboard mass transit systems using GPS navigation. From the exploration of each of these factors, it is apparent that increased civil access to the GPS signal will have a positive effect within the legal, economic and moral realms of presidential decision making.

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Chapter One

Introduction

Since World War II, the United States has yielded many of its policy decisions to the desires of the United States military. These policy decisions reach from nylon and aluminum restrictions for the war efforts of World War II through the tough military build-up policies of the 1980s amidst fiscal constraints. In the aftermath of the conflict in Vietnam, President Ronald Reagan was determined to regain America's influence in the world by rebuilding the military and strengthening the economy. In 1989, the Berlin Wall came crashing down as the prelude to the fall of the Soviet Union and the Iron Curtain of communism.

Without the apparent threat of war with the Soviet Union, the United States began to focus more on maintaining an economic and political leadership role around the world. No longer did the United States military hold a firm grip on the rudder of national policy. Instead, a balance between the amount of military power required to remain relevant in the world and economic and political influence was sought.

President Dwight D. Eisenhower, in his farewell address to the Nation in 1961, foresaw this balancing requirement: "Only an alert and knowledgeable citizenry can compel the proper meshing of the huge industrial and military machinery of defense with our peaceful methods and goals, so that security and liberty may prosper together." [1] This balance between military strength and industrial power allows the United States to project itself as the political, economic, and military world leader, using the tools available within the military and industrial complex to influence world peace and human betterment.

One of the tools provided by the military to the civilian community is the Global Positioning System (GPS). This system, originally designed for the United States military, was released for public use in a degraded form after the tragic downing of a Korean airliner by Soviet fighter aircraft after the airliner unknowingly strayed into Soviet airspace in 1983. The GPS system's full accuracy capability was not released to the public out of fear by the Department of Defense (DOD) that potential adversaries might use the system for inertial guidance of smart munitions against the U.S. [2]

Currently, there is a controversy over the possibility of expanded access to the highly accurate GPS signals heretofore available only to authorized DOD users. The decision to grant full access to the precision signal will be made by the President of the United States after weighing all of the factors which impact on the full release of this system for unrestricted civilian use.

Use of the GPS around the world has grown dramatically since public access to degraded signals was granted in 1983. Realizing the vast potential of this system, allied militaries, civil aviation, maritime industries, and private individuals have purchased the GPS receivers to improve their positional awareness for a variety of commercial and recreational uses.

The intent of this monograph is to explore the legal, moral, and economic factors that influence the presidential decision making process. The author will use the impending decision on granting full access to the GPS system to everyone worldwide as a case study of the dynamics of presidential decision making in seemingly military issues. Exploring the multiple factors that will influence an executive decision will provide the reader with a better understanding of the complexities involved in a single decision at the presidential level.

The first chapter will provide a background on the origins of the Global Positioning System as the product of a merger of United States Navy and United States Air Force positional navigation projects. Originally an exclusive Department of Defense system, the tragic downing of a Korean Airlines passenger plane by Soviet military aircraft precipitated the presidential decision to expand usage to civil aviation. This decision caused concern within the DOD that the precision positioning capabilities of the system could be used to guide weapons into close proximity of U.S. targets. DOD's answer to this potential threat was to encrypt the military signal and produce a positional signal that was degraded in accuracy, called Selective Availability, for civil use.

Although this degraded positional signal was adequate for enroute navigation, it did not have the precision that would allow aircraft or ships to operate safely in the congested areas around airports and harbors. The need for increased accuracy led the aviation and maritime communities to search for a way to improve the positional signal in the areas immediately surrounding selected larger airports and harbors. Differential GPS offered the solution they required. This system received the positional information from the GPS satellites, compared that information with its known location, and broadcast a corrected positional location.

After providing the reader with origins and events which led up to the expansion of GPS service to civilians, the first chapter concludes with an exploration of the sheer dynamics of presidential decision making. It is important that the reader gain an understanding of how complicated and interconnected the factors of presidential decision making process are. Potential impacts on the decision include the views of various government agencies, members

of congress, domestic and international law, U.S. industry, views of other nations, and international organizations.

The second chapter discusses international laws and agreements and U.S. laws and policies that the President must consider in making his decision regarding unencumbered navigation and the deprivation of available navigational information. Since the Global Positioning System is a worldwide navigational system, the navigation coverage provided by GPS across national boundaries must conform to some standard. From the earliest seafaring times, customary practice of navigational control of safety in territorial waters became more widely accepted and in time provided the precedent for international laws of navigation. This chapter will also explore the legal aspects of having a navigational system that purposefully induces error into navigational data.

The third chapter analyzes the moral factors involved in the decision. Both civil aviation and maritime industry officials believe that having access to precision navigation information is essential for the safe operation of aircraft and ships, especially in the congested areas around airports or harbors. With the current errors produced by the dithering effects of the degraded GPS signal, civil aviation and maritime industry officials believe that they cannot safely operate their craft in congested areas.

If the presidential decision is to maintain the GPS access as it is today, both industries will continue to advance technologies to counter the induced error in the system, thus nullifying the effects of purposeful degradation of accuracy. If, however, the decision is to allow access to the DOD's precision GPS signal, both civil aviation and maritime industries will have access to accurate positional navigation data that each industry claims will make operations near airports and harbors much safer.

The fourth chapter explores the economic factors that the President must consider in making his decision. Since the GPS signal was offered for public use, U.S. corporations became deeply involved in the production of GPS-related items. These include GPS receivers and accessories. In addition, these same corporations are involved in the research, development, and production of GPS satellite and ground control station components. These corporations sell the receivers and accessories worldwide at an expanding rate as more countries and individuals realize the benefits of precision navigation. Although there is a huge market for GPS products and the potential for massive economic gain for U.S. corporations, the DOD-induced navigational error for civilian receivers could weaken the demand for GPS products. Additionally, there are many foreign nations that are hesitant to rely solely on a system that is operated and controlled by the United States Military.

The fifth chapter provides a summation of the evidence presented. The author reviews the dynamics of presidential decision making, and the legal, moral, and economic factors that will influence the decision. Having considered all of these factors, the author provides some insights into what the military can learn from the exploitation of a military system into a dominant civilian instrument. By using the GPS decision as a case study, the author will provide the framework for the presidential decision making process. The considerations that will impact upon the decision include domestic policies and international agreements, transportation safety in the civil aviation and maritime industries, and the economic well being of U.S. corporations that are involved in the GPS industry.

Chapter Two

The Global Positioning System

Sixteen years after the presidential decision to allow civilian access to a military system there are still many unresolved issues including control, operation, and access to the system. Using the GPS system as a case study, the author will identify the various factors that the President will consider prior to making his decision to maintain or discontinue the Selective Availability option on the GPS satellite. This chapter is dedicated to providing an explanation of the Global Positioning System, its origins, and capabilities. The author will also discuss the DOD concerns allowing civil access to their system, the encryption employed by DOD to reduce accuracy for civil receivers, and the countermeasures taken by other government agencies to circumvent DOD's efforts. Finally, this chapter will discuss the dynamics of presidential decision making, including the factors which the President must consider in making decisions.

The United States Navy's navigation satellite system, known as Project TRANSIT, was a twelve satellite constellation situated in low earth polar orbit to provide two-dimensional passive, all weather, worldwide positioning information for ships and fleet ballistic submarines. Accurate positional information was critical for the limited range of ballistic missiles aboard the Poseidon submarines. Because only seven of the twelve satellites were operational (the remaining five were on-orbit spares), the waiting time between positional fixes varied between eight and twenty minutes. [3] TRANSIT was declared operational in January 1964. Each TRANSIT satellite was programmed to transmit its' orbital parameters and a time reference every two minutes. This data was then used, in conjunction

with the receiver's relative velocity, to calculate a two dimensional location. Because there were only seven operational satellites on orbit, orbital geometry constrained each satellite to providing this positional data four times each day. [4]

These sparse positional fixes were acceptable for Navy ships, submarines, and other slow-moving platforms. The United States Air Force's fast-moving aircraft needed a navigation system that did not require further calculation in the cockpit to determine position. Noting the limitations of the TRANSIT system, the United States Air Force began working on a new satellite positioning system that would be more responsive. The effort became known as Project 621B. [5]

The Global Positioning System was born as a merger of the United States Navy's existing TRANSIT program, their research program to improve TRANSIT called TIMATION, and the United States Air Force's Project 621B in 1973. Each of these systems relied on a passive receiver to collect the positional data from satellite broadcasts and provide an accurate position and time fix for the receiver. Essentially, the Global Positioning System satellites serve as beacons in space that transmit information to passive receivers on the ground. By using a system that relies on passive receivers, the military gains an advantage. The passive receivers do not emit an electronic footprint that could alert a potential enemy to the U.S. military's presence and provide a tracking mechanism for locating the military force.[6]

The GPS System was initially launched as a precision navigation system for the United States Military. In 1983, Soviet fighter aircraft shot down Korean Airlines flight 007 after the passenger liner unknowingly strayed into Soviet controlled airspace. Following this incident, President Ronald Reagan offered to allow civil aviation access to a degraded form of

the GPS signal to prevent that situation from ever happening again. Since the GPS signal being broadcast for the military was encrypted, DOD developed subsequent satellites that would broadcast an additional signal with degraded accuracy that could be received by civil aviation, which became known as the Standard Positioning Signal. [7]

The Global Positioning System satellites currently produce two levels of accuracy. The first level of accuracy is called the Standard Precision Signal and is available to anyone around the world who has a Global Positioning System receiver. Standard Precision Signal can provide very good accuracy for most applications. Access to the Standard Precision Signal does not require approval by the Department of Defense. There is concern within the Department of Defense that a potential enemy could use Global Positioning System to provide inertial guidance for smart munitions. To prevent this, a feature called Selective Availability was implemented, beginning with the Block II series satellites, to limit the accuracy of the Global Positioning System for users not specifically authorized by the Department of Defense. Selective Availability introduces random pseudo-range and Doppler shift error, which is also known as dithering, that reduces the level of positional accuracy. [8]

Within DOD, there was also a concern that the availability of unfiltered, accurate GPS signals to any person with a receiver could place US national security in jeopardy by allowing hostile forces to accurately direct forces and firepower in time of conflict. With presidential approval, DOD inserted a small dithering error into the timing of standard positioning signals, which resulted in a minor positional error (no more than 76 meters), for receivers of the standard positioning signal. In times of crisis, the President of the United States can direct that the degradation be increased if there is an indication that the GPS standard positioning signal may be used to threaten US national security interests and operations. [9]

The second level of accuracy, called the Precision Positioning Signal, is only available to authorized Department of Defense users with the correct cryptographic cipher installed in their receiver. These users include all U.S. military services, the Coast Guard and selected other government agencies, the military services of selected allied nations, and other designated users. The Precision Positional Signal provides the Global Positioning System receiver access to the most accurate signals from the satellites.[10] The Global Positioning System's precision signal is designed to provide an accuracy level of approximately 9 meters Circular Error Probable or about 16 meters Spherical Error Probable for a three dimensional position, anywhere in the world. Users authorized by the U.S. Department of Defense to use Global Positioning System are provided with a cryptographic key, which can be loaded into special Global Positioning System receivers. This key removes the effects of Selective Availability and allows the receiver to calculate the best solution possible. [11]

Numerous governmental and private endeavors (both U.S. and foreign) have realized the potential uses of the GPS system and have become heavily dependent on GPS signals. These uses include air, ground, and sea transportation, geodesy, and precision timing for communications networks. [12] Others, particularly foreign governments, are hesitant to rely on a navigational system that has an intentionally induced variable error and is operated by the US military. A portion of this hesitancy is due to safety considerations of placing heavy dependence on the GPS system to guide many forms of mass transit for their populace. Some nations fear that, by becoming excessively reliant on GPS, this dependence might eventually lead to a form of U.S. control over their nation. [13]

Despite the reduced accuracy of the Standard Precision Signal, the access afforded to civilians, scientists, and foreign governments has caused a dramatic increase in sales of

Global Positioning System receivers. The Global Positioning System has far exceeded the original scale envisioned by its inventors, with civilian users having outnumbered the authorized military users by a ratio of eight to one and growing. This increase in usage caused a boom in the Global Positioning System receiver production industry with the projected sales expected to reach $8.5 billion by the year 2000. [14]

Civil aviation, the intended target for the initial offering of GPS signals, was quick to begin integrating this positional service into the cockpits of their airliners. For safety reasons, the Federal Aviation Administration—another U.S. Government agency--began research into ways to provide an augmentation to the standard positioning signal that would nullify the effects of the Department of Defense's selective availability and allow civil aviation to use GPS for precision approach landings.[15]

The GPS signal available to civil aviation and maritime craft may be adequate for enroute navigation where there is less congestion, however, this level of accuracy is a safety-of-life issue when these platforms are attempting a final approach and landing or entry into a port, especially in bad weather. The need for additional accuracy of navigation signals, and the lack of compromise from DOD on selective availability, resulted in the development of the first Differential GPS (DGPS) in 1995 to provide precision accuracy in a limited area surrounding selected larger airports and harbors.[16]

DGPS is able to provide accuracy to nearly the same level as the precision signals now only available to authorized DOD users. DGPS operates using the principle of having a receiver and transmitter in the same location and knowing the precise coordinates of that location. The GPS receiver receives the broadcast position signal from the GPS satellite, calculates the error from the known position (termed a ground reference station), and

retransmits the corrected positional data within a local area. Some civilian companies, sensing a potential profit industry, began to market these DGPS systems with their own cryptographic key to paying customers as early as 1995.[17] This civil response to selective availability would effectively negate the induced error supported by DOD on a wide scale.

In 1996, the U.S. Coast Guard began deploying its own DGPS systems along the coastlines and near ports and harbors in the U.S.; offering the service free of charge in the interest of public safety in the maritime industry. Although the system was developed with a design specification of greater than 10 meter accuracy, prototype systems demonstrated an accuracy of near 1 meter.[18] In 1997, the FAA began work on its own DGPS system for use near selected major airports. The FAA also began work on a nationwide system that would improve the DGPS system known as the Wide Area Augmentation System (WAAS). WAAS provides increased accuracy, differential corrections, ranging capability, and approach guidance for civil GPS receivers on federal airways.[19]

In February 1999, Vice President Gore announced a GPS modernization initiative that would add an additional civil signal to the next generation of GPS satellites, known as Block IIF.[20] This new frequency will allow civil users, such as civil aviation and maritime operators, to use this frequency to gain the same level of accuracy as the military's precision signal. By providing this additional signal, DOD will be able to maintain their precision signal without surrendering the frequency to civil use. This civil frequency will also meet the needs of the international community for a safety-of-life application.

Under the current system, the single civil GPS signal is unable to fulfill the requirements of integrity, accuracy, availability, and reliability critical to safe operations of aircraft and watercraft in congested areas. When combined with the current civil signal, this

new frequency will significantly improve the robustness and reliability of the GPS system for civil users and will enable unprecedented real-time determination of highly accurate positions worldwide. These attributes combine to form a safer operating environment for U.S. citizens as they travel by air, land, or sea.

Thus far the origins, history, and capabilities of the GPS system have been explained. The decision to allow civil access to the GPS signal caused concerns within the DOD community, causing them to institute an intentional positional error into the civil GPS signal called Selective Availability. Other federal agencies, including the FAA and the Maritime Administration/U.S. Coast Guard, were using the civil signal to provide increased navigational safety and efficiency in the civil aviation and maritime community. These agencies felt they were unable to safely use the degraded GPS signals to vector aircraft and ships in the congested areas surrounding airports and harbors. To provide the safety to use GPS for navigation around these areas they developed DGPS to negate the effects of Selective Availability that could provide accuracy close to the level of the military's precision signal in a limited area around the airports and harbors.

The presidential decision to maintain or discontinue Selective Availability provides an opportunity to study the complexity involved in the presidential decision making process. There are many perspectives on this issue, both within the government and in the civilian community. The apparent conflict between the Defense and Transportation Departments can be seen with DOD intentionally degrading the accuracy of the civil positional signal while the Transportation Department fields DGPS to counteract the effects of Selective Availability. There are other factors which influence the President during the decision making process including the desires of foreign governments and international organizations. To better

appreciate the factors that influence the decision, the dynamics of presidential decision making will be explored next.

The GPS positioning system is a very capable, versatile, and expandable system that holds immense potential for future applications. For this reason, many agencies, governments, and civil users are providing their opinions in an effort to sway the President's decision on eliminating the intentional errors induced into the navigation signals by the Defense Department. In making his decision on the formulation of GPS policy, the President must consider the views of U.S. government agencies and industries, members of congress, U.S. public opinion, foreign governments and industries, international organizations, and legal considerations. The President relies on DOD for specific advice concerning the GPS system. However, he also looks to the secretaries of commerce, transportation, treasury, and others for their advice in their areas of expertise pertaining to the GPS system. By understanding the complexities of the GPS system and the impacts that one decision may have, the President is better prepared to make an informed decision.

In 1995, the RAND Corporation conducted a one-year study for the White House Office of Science and Technology Policy (OSTP) and the National Science and Technology Council (NSTC). The purpose of this study was to assist OSTP and NSTC in assessing alternative national objective, opportunities, and vulnerabilities in the exploitation of the GPS system as a national resource. There are several governmental agencies in conflict over the outcome of the presidential decision on providing full access to the GPS signals. As would be expected, the Defense department wanted to keep the accurate positional signals controlled as a matter of national security. The Transportation department and Maritime administration

saw the GPS system as a windfall from military research and development that would allow them to provide increased traffic with greater safety and accuracy.[21]

The issues that arise in the formulation of the GPS policy decisions include not only issues specifically about the GPS system itself but also the applications that are enabled by the GPS. In addition, the potential of this technology to create both benefits and risks for the U.S. and the world must be addressed. The benefits include increased safety through better accuracy, greater economic prosperity through increased sales and production, and control of a niche market for U.S. corporations. The Defense Department's sole objection to full access for civilians to the accurate signal is the potential risk associated with use of the GPS signal to more accurately deliver munitions against U.S. forces or targets of interest to the U.S.[22] If the President decided to remove the errors from the civilian GPS signal, hostile forces might have a better opportunity to attack U.S. forces or facilities.

With its global presence, the U.S. has been at the forefront of the development of international standards and procedures for long range military and civilian navigation. The continued development and discovery of additional uses for the GPS system have spurred additional purchases of GPS receivers by both civilian and military users. This, in turn, provides better economic conditions for U.S. corporations that are associated with the research, development, and manufacture of GPS and GPS-related products. A decision by the President to remove the error from the GPS signals for civilian receivers would provide increased potential revenues for U.S. corporations from sales and increase tax revenues for the government from those sales.

The influence of foreign governments in the decision to grant full access to the GPS signals to everyone worldwide must be considered by the President. By allowing full access

for everyone, the President would further goodwill among the nations of the world by providing a valuable service free of charge. In addition, providing the increased accuracy GPS signals to other nation's militaries will greatly improve interoperability and functionality for the increased numbers of coalition operations that the U.S. military will be involved in throughout the world. [23]

International organizations such as the International Civil Aviation Organization (ICAO) provide an influence into the President's decision. This organization provides a standardization of procedures for air traffic around the world. Additionally, ICAO is concerned with efficiency of airline operations and the safety for the passengers. Using GPS signals, the airline industry is able to save money by providing more accurate enroute positioning and trip planning information (which saves fuel) and provides better safety by helping airplanes to stay on course by knowing their exact position. Currently, ICAO is debating the possible designation of GPS as the navigational system for the Future Aviation Navigation System (FANS). If the President would decide to allow access to the precision GPS signal worldwide free of charge, this would provide an additional incentive for ICAO to designate the GPS system as the navigation standard for FANS, which would reap many benefits within the U.S. [24]

Within this first chapter, the history, origins, and capabilities of the GPS system have been documented. The presidential decision to provide the GPS civil signal resulted from the shooting down of a Korean Airlines passenger plane by Soviet fighter planes after the passenger plane unknowingly flew into Soviet airspace. DOD feared that the GPS signal might be used by hostile forces to direct weapons against the U.S. and instituted an intentional degradation of the civil signal called Selective Availability. Other governmental agencies,

feeling the need to increase the positional accuracy of the degraded civil signal for precision approaches of aircraft and ships into congested areas around airports and harbors, developed DGPS. Foreign governments and international organizations are also concerned about the accuracy level of the civil signal if they are to become dependent on it for their navigational infrastructure. Each of these provide inputs into the presidential decision making process.

Other factors that will influence the decision include the legal, moral, and economic aspects of the decision to maintain or discontinue Selective Availability, which will be discussed below. The first area to be considered by the President prior to making a decision is the legal aspects of the situation. For a worldwide system like the GPS, not only must domestic law be followed, but consideration must also be given to the international agreements and customs that provide for unhindered navigation in international airspace and water.

Chapter Three

International and Domestic laws and agreements

Exploitation of space-based capabilities is a relatively new phenomenon with few customs or traditions to provide a basis for formulating laws. The closest thing to a baseline for space law regarding navigation is maritime law, since it addresses a country's property and actions outside of that country's borders. Space can be closely associated with international waters because the vast expanse of space and open ocean belong to no single nation. This chapter will guide the reader through international laws and agreements

stemming from maritime customs and U.S. domestic laws and policies associated with the use of space for navigational purposes. The legal aspects of the decision to be made by the President can be broken down into international laws and agreements and U.S. laws and policies. International agreements may include agreements made between nations, United National resolutions, and agreements made as part of international agencies or organizations. Applicable international laws and agreements to consider when deciding this issue include customs from the Trinity House and Cape Spartel agreements and other international agreements such as the UN Territorial Convention, Law of the Sea, and Outer Space Treaty; all of which will be discussed in detail below.

Modern day laws and agreements for the uses of space were formulated from the maritime laws and customs agreed upon as early as the reign of Henry VIII.[22] In 1864, a consortium of fourteen nations built a lighthouse in response to numerous shipwrecks off Cape Spartel, Morocco and later added a signaling station in 1892. The 1892 agreement among the fourteen nations about the Cape Spartel station provided the legal precedent for the GPS selective availability decision. The agreement detailed that a signal station owned by a consortium and considered neutral can be targeted in times of war however, the navigational systems were to be maintained intact for the common good. [23]

In 1958, the United Nation's Territorial Sea Convention and the Law of the Sea Convention required nations to provide prior notice of any dangers to navigation that they have knowledge of within their territorial waters. These conventions further stipulated that each nation was responsible for providing basic navigational and rescue services inside their territory. [24] The provisions of these treaties would require the U.S. to maintain navigational aids and rescue services within its territorial waters and provide prior notice of any

environmental condition or navigational aid malfunction which would affect the safe passage of vessels. This means that, if GPS is considered the navigational means within U.S. territorial limits, the U.S. must maintain that service for safe transit and would have to provide prior notice if there would be an interruption of service.

In 1967 the United Nations proposed the Outer Space Treaty, which was later ratified by the U.S. Senate. This treaty was one of the first attempts to create an international treaty that would regulate the use of space. The relevant portions of the outer space treaty states that all nations must have the freedom to use outer space and that no nations can be denied access to outer space. The treaty further states that space activities are subject to international laws, outer space must be used for peaceful purposes, and that the launching country is responsible for any damages incurred as a direct result of the object in question.[28]

One provision of the Outer Space Treaty is that all activities in space must be for peaceful purposes only. The dual use of the GPS system by the U.S. military appears to be no more in contravention to the treaty specifications than military communications and imagery satellites that operate in both war and peace.[29] Another provision in this treaty is the assertion that the launching country is responsible for the damages incurred by the space object. It is unclear if the intent of the treaty is to provide liability for damages caused physically by the spacecraft or if the damage could result from information given by the satellite, i.e. false navigational data. If the latter interpretation is included, this could provide a huge liability for the U.S. if reliance on GPS signals produces damages within the civil aviation, maritime, allied military, and individual civilian user communities. By intentionally introducing error into the standard positioning signal, the United States is providing a false navigational fix which could result in the loss of life and damage to facilities and equipment.[30]

Thus far we have explored the international laws, customs, and agreements that form the basis for navigation today. These include the agreement over the navigation and signal stations at Cape Spartel which stated that the communications portion of the station could be shut down by any member nation in times of war, but the navigation portion must be maintained for the public good. Additionally, the 1958 Territorial Sea Convention and Law of the Sea specify that each nation is responsible for the safe navigation of vessels within their territorial limits and prior notice is required if a condition existed that could endanger the safe passage of vessels. The last international treaty examined was The Outer Space Treaty of 1967. This treaty specifies that space is available to all nations for peaceful purposes, no nation can be denied access, and that any damage incurred from the satellite is the responsibility of the launching nation.

These international laws and agreements have a direct impact upon the President's decision to maintain or discontinue Selective Availability. The 1982 Cape Spartel agreement provides a precedent for the maintenance of the GPS signal for the public good, even in times of war. The 1958 Territorial Sea Convention and Law of the Sea dictate the requirement of the U.S. government to provide safe navigational signals within the U.S. territorial limits. It further requires the U.S. to provide prior notice if there are conditions, such as decreased GPS accuracy, that could endanger the safe passage of persons through U.S. territory. The Outer Space Treaty of 1967 provides the basis for potential for U.S. liability caused by the GPS satellite degraded positional accuracy signals. These broadcasts of intentionally incorrect positional readings could cause damage to craft or vessels using those signals as their navigational system. However, the fielding of DGPS for use in the congested areas around selected airports and harbors may mitigate this liability.

The other portion of the legal factors the President must consider are United States laws and policies, including statements of national policy and intent. The author was unable to find any domestic laws concerning the use of space-based systems for navigational purposes.[31] Therefore, the guidance and announcements released by the President and his agents serve as our national policy. In making his decision on the limits of access allowed to the GPS satellite navigational signals, the President will have to consider the policies he has set forth. These include the National Space Policy, The U.S. Global Positioning Policy, the Federal Radio-navigation Plan, Presidential Decision Directive (PDD) 6, regulations administered by the Federal Aviation Administration (FAA) and the Maritime Administration/U.S. Coast Guard, and various press releases. Although policies from each successive President may change slightly, they will generally not deviate far from the previous administration because the earlier policy becomes an established precedent and any radical deviation may bring congressional reaction, media focus, and a change in public opinion.

The U.S. National Space Policy, approved by the President in 1996, states that the U.S. will "support a strong, stable and balanced national space program that serves our goals in national security, foreign policy, economic growth, environmental stewardship, and scientific and technical excellence."[32] Each of these areas are fundamental to the decision the President will have to make regarding the discontinuation of introducing error into the GPS standard positioning navigational signal. Although national security is a significant concern, the President must also weigh the impact his decision will have on the U.S. economy, the nation's technology base, and foreign relations.

The President's theme within the National Space Policy is that space should be used by all nations for peaceful purposes and to provide benefit for all mankind.[33] Certainly the GPS navigational signals are available to anyone who has a receiver. The civil uses that the GPS navigational signals have been used for thus far have provided for a safer and more efficient world. The National Space Policy of 1996 further states that the U.S. has the right to defend itself in times of emergency. This statement provides the basis for maintaining the selective availability option for GPS signals, since the Department of Defense continues to assert that potential adversaries could accurately target precision munitions against U.S. forces or territories using the precision GPS signal. By dithering the signal to greatly reduce the accuracy available to standard positioning signal receivers, adversaries attempting to use GPS signals to provide terminal fixes for precision munitions would be further from the intended point of impact.[34] This portion of the National Space policy is in direct conflict with the 1892 Cape Spartel agreement which specified that navigational information cannot be withheld, even in times of conflict.

In March of 1996, the President approved the U.S. Global Positioning System Policy; further refining the future management, use, and augmentation of the global positioning system. Specific goals within the GPS policy include strengthening and maintaining our national security, encouraging acceptance and integration of GPS into peaceful civil, commercial, and scientific applications worldwide. The GPS policy further desired encouragement of private sector investment in and use of GPS technologies and services, promotion of safety and efficiency in transportation and other fields, promoting international cooperation in using GPS for peaceful purposes, and advancing U.S. scientific and technical capabilities.[35]

This policy echoes the National Space policy in the desire to use GPS for peaceful purposes and promoting safety while simultaneously strengthening and maintaining our nation's national security. The emphasis of this policy is on public safety and sharpening the military edge as the U.S. military moves more towards high technology operating systems. By encouraging acceptance and integration of GPS into peaceful civil, commercial, and scientific applications worldwide, United States corporations can expand their market share in GPS-related research, development, launch, and retail sales leading to additional revenue for U.S. corporations and greater economic prosperity for the United States.[36] The U.S. is able to advance their scientific and technical capabilities with the launch and operation of every satellite. Using the performance data of each satellite, scientists can learn from the mistakes of the past, integrate new materials and techniques, and design even better satellites for the next block revision. Continued research and development leads to lighter, more efficient, and better performing spacecraft and increases the knowledge base within the scientific community.

The GPS policy further delineates the acceptance of GPS enhancements, such as differential GPS systems, which would be placed at major airports and harbors to provide precision location capabilities that would nullify the effects of the induced error in the standard positioning signal. This statement creates confusion in understanding the President's intent. On one hand, the Department of Defense is providing the GPS service with a deliberate degradation for civil use. On the other hand, the Department of Transportation is using Differential GPS to overcome the intentional errors placed into the system with the selective availability option. There are cases, including Washington, D.C., where the U.S. Coast Guard's maritime DGPS coverage defeats the selective availability errors thus

providing precision navigation capabilities over the very military facilities that selective availability was designed to protect.[37] The contradiction amongst the government agencies provides no gain and, in the end, wastes funds and extensive effort that could be put to use elsewhere.

The other major document that provides guidance on the provisions of the GPS system for navigation is the Federal Radio-navigation Plan (FRP). This plan, best thought of as a road map or spider web, provides the framework for the various navigational aids used by aviation and maritime craft and explains how they interrelate and provide coverage throughout the United States.[38] This document also delineates responsibility for operations, management, and upgrades to each segment of the radio-navigation network. The FRP provides the overall plan for navigation within the territorial limits of the United States including the use of GPS-aided navigation. The plan serves as a signal of the importance that GPS navigation plays in the future of the United States' transportation infrastructure.

Besides written policies and plans, presidential decisions can also be made through announcements. In 1996, the Vice President and the Transportation Secretary announced the signing of a Presidential Decision Directive (PDD) Six which would allow civilian and commercial use of the GPS system and asserted that the United States would keep the twenty four satellite constellation operational and free of charge.[39] The Vice President further stated that GPS would soon be put to use by motor carriers, rail and transit vehicles, airlines, and commercial shippers worldwide to track vehicles and goods and provide highly accurate three dimensional position, velocity, and time. This PDD served as a reinforcement of President Reagan's declaration of guaranteed access for civilian and commercial users.[40]

After considering the policies, plans, and directives that he has endorsed, the President must also consider the federal regulations for those industries that rely on GPS signals as an integral part of their navigation procedure, such as civil aviation and maritime industries. The activities of these industries are regulated by agencies within the federal government because of the magnitude of transportation systems and the concern for public safety. Both the Federal Aviation Administration (FAA) and the Maritime Administration (MA) have established strict regulations to provide standard operating procedures and limitations for air and sea travel because of the inherent dangers associated with operating aircraft and ships. [41]

Last among the legal influences the President must consider are announcements of intention. In 1997, Vice President Gore announced an agreement between the Secretaries of Defense and Transportation on the capabilities of the next generation GPS satellite. This next generation satellite, known as Block IIF, will have a second frequency installed that will provide guaranteed, uninterrupted access to GPS signals for civil users while maintaining the military GPS signal encryption.[42] This announcement provides reassurance to both DOD and to civil users of the GPS system. By producing a second civil signal, DOD can maintain its own encrypted signal for precision navigation while providing a clear signal for civil receivers. This announcement does not, however, provide any clear guidance or indications on the intention to discontinue selective availability.

In 1999, Vice President Gore announced the GPS modernization initiative to add two new signals to the GPS satellite output. The addition of the second civilian signal is intended to provide even better access and reliability using a different frequency. [43] By broadcasting a second navigational signal from a different frequency, there is a greater amount of reliability through redundancy. In other words, if one signal were jammed or inoperable, the second

signal at a different frequency would still be available to provide the needed navigational data. This additional step to increase reliability for civil users may lead to a greater demand for GPS products and may increase the economic prosperity of U.S. manufacturers. This announcement attempts to provide civil users with demonstrated commitment to maintaining civil access to GPS signals, but does not provide any insight into the impending selective availability decision.

This chapter has provided the historical precedents, customs, and traditions that have become the basis for international law and agreements. From an international legal standpoint there are three factors to consider. The 1892 Cape Spartel agreement dictates that the GPS navigational signal must stay on even during times of war. The 1958 Territorial Sea Convention and Law of the Sea dictate the requirement of nations to provide for the safe passage of vessels through their territory and to provide prior notification of impending dangers to navigation. The Outer Space Treaty of 1967 specifies that the launching nation is responsible for damages caused by its' satellite. A conflict within U.S. domestic policy regarding GPS is apparent in the National Space Policy regarding the 1892 Cape Spartel agreement; stating that the GPS civil signal could be terminated in times of conflict or war. The President's stated goals for the GPS system include encouraging international acceptance of GPS and increasing the technical and scientific knowledge base within the U.S. community. By dedicating two GPS signals on different frequencies, the President is providing reliability and the promise of assured future access that will help to encourage international acceptance of the GPS system.

Thus far, we have explored the origins of the GPS satellite system, its capabilities, the complexities of presidential decision making, and the legal aspects of the impending decision

on Selective Availability. Other factors that will impact on the President's decision include the moral and economic considerations. The moral factors include the safety of humans as they use the GPS system to provide navigational information for mass transit applications. A decision to discontinue Selective Availability may increase the safety of passengers and confidence of GPS users. The economic factors include the current revenues generated from research, development, launch, operation, and retail sales within U.S. corporations. Discontinuation of Selective Availability may provide increased revenues through the sales of additional receivers for diverse applications, which will increase the industrial power of the United States. A discussion of the moral and economic factors follows.

Chapter Four

GPS and the Moral Factor

Previously, the monograph examined the GPS system and its origins and the basis for modern day navigational laws and agreements. This chapter is dedicated to studying the moral factors of presidential decision making. The World Book Encyclopedia Dictionary defines moral as "good in character or conduct; virtuous according to civilized standards of right and wrong; based on the principles of right conduct rather than on law or custom."[44] Thus according to this definition, in making a morally correct decision, the President would do what is right according to civilized standards rather than basing his decision on existing laws or customs. Conveniently, the laws and agreements that have been previously discussed have as their foundation the civilized standards from early seafaring days. Two

considerations that will impact the President's decision within the moral factor include the safety of U.S. Citizens and the effect that this decision will have on the American public's opinion of the President.

The United States has always considered the safety of its citizens, both within the country and while travelling or living abroad, to be an important consideration when making decisions or formulating policy.[45] When deciding the issue of the intentional degradation of GPS signals for civil use, the President must consider the possible consequences of decreased accuracy. The consequences of decreased accuracy for civil aviation and maritime traffic could be jeopardizing the safety of the citizens on board those transportation platforms.

The U.S. Department of Transportation is the government agency responsible for the control and safe passage of commercial and private transport throughout the United States. The Departments of Defense and Transportation are at odds over the issue of degrading positional accuracy of the GPS signal for civil use. The presidential decisions discussed in the previous chapter have provided commercial and private air and sea community with confidence in their ability to access a responsive and reliable navigational system for years to come. The results of this confidence have been an increase in GPS end item sales, as will be discussed later.

While the Department of Defense views the GPS as a military force enhancement, the Department of Transportation sees the opportunities that GPS can provide in terms of cost savings, efficiency, and safety. Both Department of Defense and Transportation expect the GPS system to play an increasingly important role in accomplishing their missions in the future; which has resulted in more fielded military and civilian systems with integrated GPS navigational systems.[46] In 1996, Transportation Secretary Pena described the GPS system as

an innovation that would allow the U.S. to take a giant leap ahead in safety. [47] As more and more companies enter into the commercial and private air and sea transportation business, the DOT is becoming increasingly challenged to provide high reliability navigation information for an increasingly crowded and complex national air and water transportation network.

The capabilities of the civil GPS signal for accurate positional information, when augmented by Differential GPS accuracy enhancement, have provided air traffic controllers with a better capability in controlling aircraft. This DGPS accuracy is available within a limited area around the larger airports and allows air traffic controllers to know the exact location and altitude of aircraft within that area. With increasing numbers of commercial and private aircraft operating in and out of controlled airports, the air traffic controllers are able to provide an increased level of safety in knowing precisely where every aircraft is. This accuracy is addictive and can cause a dangerous level of comfort. The accuracy of the DGPS system allows air traffic controllers to decrease the intervals between arriving and departing aircraft, however less physical space between aircraft decreases the previous margin for error. This physical separation between aircraft becomes even more critical in cases where emergency conditions dictate that a pilot make rapid and abrupt maneuvers to land a malfunctioning aircraft. [48]

The discussion on air traffic control so far has revolved around a single airport operating with DGPS augmentation. The national air transportation network, in contrast, is made up of the sum of all of the airports within the U.S. An additional layer of complexity is added when the national air transportation network is overlaid upon an international/global air transportation network. Each of these airports can be best thought of as interconnected hubs where true positional accuracy is available within the hubs but selective availability produces

degraded accuracy outside the hubs. The levels of accuracy that air traffic controllers rely upon within the DGPS hubs allows them to condense the separation between aircraft, however the decreased accuracy outside these hubs could result in increased safety risk if aircraft do not increase separation distances. As more and more transportation platforms enter the operating space, the need for increased accuracy in vectoring these platforms is essential.[49]

Clearly, the civil aviation and maritime communities are ready to accept the military levels of GPS accuracy and have voiced their desires to the President. This level of accuracy would allow an increased measure of safety in separation outside of the DGPS coverage areas. The need for increased accuracy will become even more critical as more transportation platforms enter the skies and seas. The second moral factor to be examined is the reaction of the American public. The administration expected the announcement of increased public safety with the expanded use of DGPS to draw a reaction from the American public. Although the civil aviation and maritime communities have provided their input for the decision, the next question is what do the American people think about this issue and what were their reactions to the administration's promises of increased safety?

On February 27, 1997, a joint press release from the Departments of Defense and Transportation announced the addition of another GPS civil signal. This additional civil GPS signal allowed the President to declare an increased level of safety that GPS would provide for domestic or international travel by air or sea. Despite the fanfare of this announcement, the new generation of GPS satellites that will have this additional civil signal is not scheduled for launch prior to 2005. Previously in this chapter the safety of the populace was discussed as one of the factors which influences the presidential decision making process. This proclamation of a second civil GPS signal served a two-fold purpose of gaining public

approval through the announcement of additional measures to improve public safety. Intuitively, a President who ignores the welfare and interests of his or her constituency will have a harder time convincing those voters to re-elect them during the next election. [50] In the case of our current President, on his second term, his concern is not about his re-election but rather the public perception of the party he represents and the election of his party's next presidential nominee.

But just how much does the U.S. populace care about the announcement of a second civil signal for the GPS? Generally, the voice of the people can be heard through the written media in the form of letters to the editor, authoritative editorials, and political articles. In order to find an answer to this question, the author chose 4 major newspapers to document the announcement of the presidential decision and look for public reaction. The author chose *The New York Times, The Los Angles Times, The Washington Post, and the Wall Street Journal.* The time period for review was from one week prior to the announcement until 3 weeks after the announcement. For each paper, the sections reviewed included the headlines, the Op/Ed section, the technology section, and the politics and policy section. [51] Typically when there is an impending announcement that is hoped to provide a desired reaction or effect from the populace, there would be articles or editorials voicing the opinion of the author either for or against the impending announcement. In the week preceding the announcement, there were no articles or other discussions about the significance of neither the announcement nor any voice of dissent. Why was there no public reaction prior to the announcement? Did the people this measure was intended to provide increased safety for not care?

Following the announcement, each paper published a short article that provided some history about the GPS system, its capabilities and current applications, and an explanation of

the benefits of the President's announcement in the technology section. For the next three weeks, the author reviewed the target newspapers for the public's reaction to the President's announcement. The author reasoned that the reaction to the decision would come within that timeframe and would most likely be in the Op/Ed, letters to the editor, or technology section. After the announcement was made and the publishing of the information article by each newspaper, there was no further mention of the issue in any of the newspapers reviewed. Despite the attempts of the federal bureaucracy to win favorable support from the general public in what was proclaimed as a giant leap ahead in safety for all Americans, the message received no response. Americans just did not care.

This chapter has discussed the moral factors of safety and public opinion within the confines of the impending GPS selective availability decision. The GPS navigational system has proven itself to be a highly accurate positioning system. The Transportation Secretary said the use of GPS positioning for transportation platforms was a giant leap ahead in safety for all Americans. The addition of two separate frequencies for civil use will increase the reliability of the system. However, if the President was intending to use this issue as a method of gaining favorable public support, a review of various newspapers would make one think the issue fell upon deaf ears. There was neither positive nor negative reaction to the President's announcement-the populace was unresponsive. Up to this point, the factors of legal and moral impacts have been discussed. In the final chapter of the monograph, the last factor of economic impacts will provide the reader with a perspective on the potential monetary gains or losses that can result from this presidential decision.

Chapter Five

GPS and the Economy Factor

GPS's popularity is expected to grow in waves as different markets adopt the technology. Equipment sales at first were predominantly military but eventually moved into the surveying market as the constellation grew. Upon the decision by President Reagan to provide the GPS signal in a degraded form to civil users, these users began to realize some of the potential applications of this positional technology. With the constellation complete and hardware costs continuing to decline, the fastest growing segments for GPS sales are expected to be mass consumer markets which add functionality to cars, computers, and mobile communications. Other major civilian applications include car navigation, tracking, surveying and mapping, geographic information systems, civil aviation and maritime industry. [52] The economic factors involved in the President's decision on maintaining or discontinuing selective availability for GPS can be divided into military spending, civilian cost, and the monetary impact of increased accuracy.

As a military system, DOD initially provided the research, development, acquisition, and operation funds for the GPS satellite system. A baseline estimate for the annual cost that DOD pays for the GPS system, which includes four launches, five ground stations, and one control center is approximately $400 million. Since the program began in 1973, DOD has invested more than $8.5 billion into the GPS program. [53] The program for the next generation of GPS satellites, known as Block IIF, are expected to cost DOD approximately $6 billion with the first launch scheduled for the year 2004. [54] This next generation of satellites, if the

reader will recall, are the much-lauded GPS satellites with two separate civil signals to increase accessibility, reliability, and responsiveness for the user.

Military programs, such as the GPS program, provide monies to maintain a warm industrial base and further the research and developments efforts to stay on the leading edge of technology. The result of initial military expenditures is a ripple effect that represents an economic food chain. As money is provided to the industry, those funds become seed money for other projects within that same field of endeavor. This food chain provides a common focus of effort, provides savings through economy of scale, and produces technological benefits, increased capabilities, and broader applications for both the military and commercial community. [55] Revenues from commercial sales of GPS receivers and associated equipment resulting from dual use military technologies have supported research and development investments by corporations. These investments in a potential high sales market have led to new innovations and applications for GPS technologies that require no government expenditures. The results of the U.S. corporate interest in GPS technologies are international patents, declining prices for receivers, and increased export sales. Additionally, the lower cost, lighter weight, and higher performance of commercial receivers have set a stringent, competitive benchmark for military receiver manufacturers. [56]

Vice President Gore, in a March 30, 1998 speech stated "GPS becomes the engine of economic growth and efficiency as businesses and consumers are constantly developing new and creative applications for the system. We will do everything we can to protect the GPS signal and promote GPS applications for commerce, public safety, and national security purposes." [57] This promise serves to assure U.S. corporations and foreign governments that their investments will be secure and profitable. Without these assurances and acts of good

faith that GPS signals will continue to have free and reliable access, GPS manufacturers may seek other opportunities for investment.

Unlike other DOD procurements, commercial stakeholders in GPS extend beyond just those seeking to compete for contracts. It includes firms supplying GPS products to the private sector directly, firms that use GPS products to enhance the competitiveness of their products, firms using GPS products to meet customer needs, service providers, and firms that benefit from the improvements brought about by GPS technologies. [58] Competitive pressures on hardware prices will create incentives for GPS manufacturing firms to add value to the receivers with software and service niches in their existing markets. [59] GPS is likely to become an add-on capability for end items, much the same as modems or sound cards are for computers. If the price is affordable and little training is required to operate the GPS receivers, more consumers will be tempted to purchase a GPS. [60] The combination of affordability and simplicity serve to increase revenues for U.S. corporations. If, however, the access is limited or degraded, corporations and consumers may seek other products that have a better chance for utility. If producers and consumers move away from the GPS market, sales will obviously fall due to higher prices and more of the research and development costs will fall back onto DOD. Thus, the decisions made by the President concerning GPS access will impact market growth and corporate investment in future GPS technologies and applications.

As the civil community continues to expand the technological capabilities of GPS, U.S. corporations are surpassing the proportion of money being spent by the military. In 1993, after the military placed its 24th satellite into orbit, the commercial market for GPS had already developed into a $2 billion per year enterprise. [61] The civil applications being created

by American corporations are currently outstripping military applications by over eight to one. [62] As the perception of future potential economic gain by corporations increase, these corporations are more willing to fund research and development efforts that will yield them technological discoveries and patent rights for dual use applications. Growth in civil GPS equipment sales in 1990 was $80 million and is projected to be more than $8.5 billion by the year 2000. Industry officials further projected that sales would be $30 billion by the year 2005 with the creation of over 100,000 new high technology jobs, based upon the expansion of the civil market into more diverse applications and the increased usage of a more precise, reliable GPS navigational system. [63] In a 1996 RAND study, export sales of GPS products were expected to provide more than half of all GPS sales with a market share of 52%.[64] With the majority of all GPS sales now being made in the export market, what was once considered to be just a domestic decision now appears to have a global impact.

As GPS applications become more sophisticated they are also becoming more deeply embedded in economic activities. [65] As capabilities and applications expand, GPS technologies are becoming more embedded in the functions of international telecommunications and transportation networks as well as the military systems of the armed forces. As an example, the Dallas Area Rapid Transit authority recently selected GPS for automatic vehicle location for its 850 buses, 150 vans, 40 rapid transit rail cars, and 100 transit police vehicles operating over 1,000 square miles covering 3 counties and a major metropolitan area. [66] So extensive is this embedding that the losing access to GPS is considered intolerable. [67] With increased reliance on GPS signals globally amongst numerous applications, the question is no longer whether to allow access but rather what is the economic gain possible.

Within this chapter, the author has shown the economic and technological results of granting civil access to the GPS signal. Initially, the GPS program was a military exclusive project with no civil corporation incentive to 'buy into' the technology. Once civil access was granted, American corporations began to realize the potential gains that could be harvested from creating more applications for this navigational technology. To capitalize on this, corporations were funding more of the research and development efforts. The results of the increased research and development funds allocated by corporations provided technological advances, increased efficiency in production, and lower retail commercial receiver prices. These by-products have created mutual benefits for both DOD and civil corporations by producing better products that are also affordable for civil users; increasing economic gains for the corporations while maintaining a warm industrial base. Having looked at the economic benefits of military and civil research, development, and production, the issue of monetary impacts resulting from increased accuracy must be explored.

The GPS navigation system capitalizes on the substantial energy savings available from improved navigation over long routes for both ships and aircraft. A substantial environmental saving is also possible through disaster avoidance for ships carrying hazardous substances. An example of environmental savings could have resulted if the Exxon Valdez had been equipped with GPS navigational devices that would have prevented its running aground and spilling large quantities of oil into Prince William Sound in Alaska. These environmental savings, however, are very difficult to quantify until after a disaster has occurred. Using the airline industry as an example of the impacts of increased accuracy provides stunning quantifiable results. These results can be measured in decreased operating costs and increased measures of performance. Operating costs associated with increased

accuracy are most easily measured in fuel consumption. Measures of performance include pilot workload, on-time arrivals, and poor weather operations.

The increased accuracy gained with the GPS precision navigation capability is anticipated to provide more direct routes for airlines between departure and destination airports. Currently, airlines fly on designated federal airways that link the various VOR and NDB beacons together into the national airspace. If the precision GPS signals were available for civil use, airlines would be able to fly direct routes to destination airports; using the network of beacons as a back-up navigation source in the unlikely event of a catastrophic failure of the GPS system. In monetary terms, the cost savings in fuel for the airline industry realized through more direct routes equates to approximately $5 billion annually. [68]

With the all-weather capability of the GPS system, airlines can expect to be able to operate in weather that was considered unfavorable for the beacon navigation system. The GPS system can also accurately calculate the aircraft's ground speed and arrival time at the destination airport; allowing the pilot to adjust the aircraft's speed. Additionally, course corrections due to winds aloft are more easily accomplished with the GPS. These will result in more on-time arrivals to destination airports for the passengers. [69]

Pilot workload in the cockpit would be greatly reduced with the adoption of the precision GPS as the primary source of navigational information. In the author's own personal experience using even the degraded GPS signal, the amount of work required of the pilot in the cockpit during flight is greatly reduced. This results from all of the navigational information coming from a single screen. This screen will indicate the desired course to destination, any course corrections required, current ground and airspeed, and a graphic display of the terrain over which the aircraft is flying. This is contrasted with a pilot flying

without a GPS having to constantly monitor at least two screens as well as consulting maps and airport directories to gain the same information in a more time consuming manner.

When considering all of the advantages of the precision GPS navigation system, the airline industry appears to be more than willing to accept it as their primary source of navigation information. Captain Bill Cotton, manager of air traffic systems for United Airlines, claimed the airline lost $500 million annually due to ATC inflexibility, bad weather delays, inadequate airspace capacity, and fuel loss. Captain Cotton projected that his airline would recoup at least half of the annual loss with the adoption of the precision GPS navigation system. [70] This lost revenue could be used by the airline to provide improved service or to reinvest into capital investments, such as new equipment or aircraft, which would increase the monetary gain within the U.S. economy.

This chapter has shown that from an industry perspective, allowing access to the precision GPS signals would save money for U.S. corporations that could be reinvested into the economy. The prosperity produced from the increase in GPS applications would further strengthen the economy and provide incentive for civil research and development for increased capabilities or applications. Each new leap ahead in technology serves to maintain or increase the United States' technological lead over other nations of the world. Further growth in the GPS industry depends on the continued supply of stable, high quality GPS signals, international acceptance of commercial GPS products and services, and the absence of competing systems and technologies providing similar benefits. [71]

Chapter Six

Conclusion

The GPS is a valuable navigational tool for the United States government with an almost limitless capability for increased application in military and civil sectors. The monograph has provided the historical background on the GPS system and how it became available for commercial use. The impending decision by the U.S. President to increase civil access to GPS includes legal, moral, and economic factors.

For a worldwide system like the GPS, not only must domestic law be followed, but consideration must also be given to the international agreements and customs that provide for unhindered navigation in international airspace and water. From an international legal standpoint, three things are apparent. The GPS navigational signal must stay on even during times of war, nations are required to provide for the safe passage of vessels through their territory and to provide prior notification of impending dangers to navigation, and the owning nation is responsible for any damages caused by its' satellite. Domestically, the President's stated goals for the GPS system include encouraging international acceptance of GPS and increasing the technical and scientific knowledge base within the U.S. community. By dedicating two GPS signals on different frequencies, the President is providing reliability and the promise of assured future access that will help to encourage international acceptance of the GPS system.

The moral factors of safety and public opinion are important within the President's decision making process. The GPS navigational system has proven itself to be a highly accurate positioning system. The Transportation Secretary said the use of GPS positioning

for transportation platforms was a giant leap ahead in safety for all Americans. The addition of two separate frequencies for civil use will increase the reliability of the system. However, if the President was intending to use this issue as a method of gaining favorable public support, a review of various newspapers would make one think the issue fell upon deaf ears. There was neither positive nor negative reaction to the President's announcement-the populace was unresponsive.

Allowing access to the precision GPS signals would save money for U.S. corporations that could be reinvested into the economy. The prosperity produced from the increase in GPS applications would further strengthen the economy and provide incentive for civil research and development for increased capabilities or applications. Each new leap ahead in technology serves to maintain or increase the United States' technological lead over other nations of the world. Further growth in the GPS industry depends on the continued supply of stable, high quality GPS signals, international acceptance of commercial GPS products and services, and the absence of competing systems and technologies providing similar benefits.

In summary, the decision by the President will impact the nation legally, economically, and morally. By increasing access to the GPS signals, the U.S. will have provided the required navigational devices for transit within the confines of its territory. The decision to increase civil access to the GPS signals will increase the number of civil applications available for GPS. An increase in applications will result in more production, lower prices, and increased demand for GPS products. Increased sales mean more prosperity for U.S. corporations and the U.S. economy. Morally, with increased GPS access, the President will provide greater safety for U.S. citizens, as well as all travelers onboard mass transit systems using GPS navigation. From the exploration of each of these factors, it is

apparent that increased civil access to the GPS signal will have a positive effect within the legal, economic and moral realms of presidential decision making.

ENDNOTES

1. "Eisenhower's Farewell Address to the Nation," January 17, 1961 [document on-line]; available from http://mcadams.posc.mu.edu/ike.htm; Internet, accessed September 24, 1999.

2. "Space Wars," [document on-line] by Katherine Peters is available at http://www.govexec.com/features/0498s1.htm; Internet, accessed August 28, 1999.

3. Bob Preston, Plowshares and Power; The Military Use of Civil Space, (Washington, D.C., National Defense University Press, 1997), 249. For slow moving platforms, such as ships and submarines, the time between positional fixes was adequate for their needs. As aircraft technology progressed, the need for more rapid positional fixes became apparent.

4. G.D. Dunlap and H.H. Shufeldt, Dutton's Navigation and Piloting, (Annapolis, MD, Naval Institute Press, 1972), 580-588.

5. Bob Preston, Plowshares and Power; The Military Use of Civil Space, (Washington, D.C., National Defense University Press, 1997), 249-250.

6. Scott Pace provides an explanation of the GPS system's operation in "The Global Positioning System; Assessing National Policies," (Santa Monica, CA, Critical Technologies Institute, 1995), 237-239. A Global Positioning System receiver has to acquire and track signals from Global Positional System satellites, achieve carrier and code tracking, collect data from the satellite broadcast message included in the signals, and then calculate the receiver's range and relative velocity. From this data set, the receiver can then display the current universal time, positional data and the speed of the receiver; the output display data can be individually configured for each receiver (i.e. miles versus kilometers, map grid system, etc.). For a receiver on the ground to determine its 3-dimensional position it must calculate the four unknowns of latitude, longitude, altitude and time. For this reason the ground receiver must receive signals from at least four satellites. To calculate a 2-dimensional position (no altitude) requires three satellites to be in view of the receiver. With the 24-satellite constellation in orbit there are no less than six satellites in view anywhere in the world most of the time. The Global Positioning System uses triangulation to find the precise position of the receiver. The receiver will select satellites that are farther apart in the sky to provide the most accurate position solution using the satellite position information and timing data, called the almanac, which is stored and periodically updated in the receiver.

7. "Global Positioning System," [document on-line]; available from the U.S. Coast Guard Navigation Center Home Page at http://www.navcen.uscg.mil/faq/gpsfaq1.htm; Internet, accessed September 14, 1999.

8. Doug Richardson, "GPS in the Shadows of NAVWAR," Armada International, (Aug/Sep 1998): volume 22, page 22. The DOD agreement to maintain a dithering of no more than 100 meters during peacetime continues to be a matter of contention for civil aviation and maritime users, as well as military users from other nations. This intentionally-induced error has provided the impetus for the research and development of ways to defeat this system.

[9] The precision levels expected can be found within the Chairman of the Joint Chiefs of Staff Instruction number 6130.01a, "CJCS Master Navigation Plan," February 13, 1998 [document on-line]; available from http://www.dtic.mil/doctrine/jel/cjcsd/cjcsi/6130_01a.pdf; Internet, accessed August 24, 1999.

[10] Ibid. The rapid timing within the GPS system is the basis for the precision of the GPS satellites to provide the user with accurate location and elevation. Each Global Positioning System satellite has atomic clocks on board to maintain accurate time. Data on the status and accuracy of these atomic clocks are sent to the Global Positioning System Control Center. Corrections are sent to the satellites whenever necessary to keep the system within specification. Atomic clocks are not nuclear powered. They get their name because they use the very stable oscillations of certain elements, often rubidium or cesium, to measure the passage of time. The velocity accuracy is 0.1 meters/second RMS. Time accuracy is 100 nanoseconds (billionths of a second).

[11] Scott Pace describes the GPS's level of accuracy in "The Global Positioning System; Assessing National Policies," (Santa Monica, CA, Critical Technologies Institute, 1995), 237-239.

[12] Scott Pace describes the many uses for GPS, including the criticality of the timing function, which is relatively unknown in "The Global Positioning System; Assessing National Policies," (Santa Monica, CA, Critical Technologies Institute, 1995), 100.

[13] Frank Vizard, "New Direction for GPS," Popular Science, (December 1996): Volume 249, page 93.

[14] Bruce D. Nordwall, "RAND Recommends Military Control of GPS," Aviation Week and Space Technology (February 12, 1996) 44-45. The increase in civil users has provided a challenge to Department of Defense control of the GPS constellation.

[15] DGPS information can be found on the U.S. Coast Guard Navigation Center Home Page at http://www.navcen.uscg.mil/faq/dgpsfaq1.htm; Internet, accessed September 9, 1999.

[16] DGPS benefits are described on the U.S. Coast Guard Navigation Center Home Page at http://www.navcen.uscg.mil/faq/dgpsfaq1.htm; Internet, accessed September 2, 1999.

[17] Bob Preston, Plowshares and Power; The Military Use of Civil Space, (Washington, D.C., National Defense University Press, 1997), 294-295. The author describes the commercial attraction that DGPS has provided. This movement was squelched when the USCG installed their own DGPS thus providing a disincentive for civilians to pay a commercial venture for a service that is available for free from the USCG.

[18] "Federal Radio-Navigation Plan," United States Coast Guard Navigation Center Home Page [document on-line]; available from http://www.navcen.uscg.mil/policy/frp1996/frp.pdf; Internet, accessed September 2, 1999.

[19.] Scott Pace provides an explanation of the FAA's WAAS that will provide DGPS accuracy along the gederal airways in "The Global Positioning System; Assessing National Policies," (Santa Monica, CA, Critical Technologies Institute, 1995), 128-129.

[20.] The new technologies to be integrated into the new Block IIF GPS satellite systems are described on the U.S. Coast Guard Navigation Center Home Page at http://www.navcen.uscg.mil/gps/geninfo/i2r.htm; Internet, accessed September 24, 1999.

[21.] Scott Pace, et al The Global Positioning System; Assessing National Policies, (Santa Monica, CA, Critical Technologies Institute, 1995), 24.

[22.] Doug Richardson, "GPS in the Shadows of NAVWAR," Armada International, (Aug/Sep 1998): volume 22, page 22. DOD continues to object to the expansion of the military signal for civil use because of the possibility of an adversary using the precision signals to provide terminal guidance for munitions against US forces or interests.

[23.] William Drozdiak, "War Showed U.S.-Allied Inequality," Available from the DOD Early Bird at http://ebird.dtic.mil/Jun1999/e19990628showed.htm; Internet, accessed September 19, 1999. Drozdiak explains the benefits of interoperability in NATO and coalition operations, including GPS access, in this June 28, 1999 Washington Post article.

[24.] Robert W. Moorman, "Delaying the GPS Promise," Air Transport World, (SEP 93): Volume 30, page 36. Moorman provides an early explanation of the Future Air Navigation System (FANS), which is seen as the worldwide integrated navigation network with the GPS satellite system as the centerpiece.

[25.] John Columbos, The International Law of the Sea, (New York, NY, David McKay Publishing, 1967), 334. In response to the widespread practice of setting signal fires to deliberately lure ships onto England's coasts, Henry VIII established an organization known as the Trinity House to erect lighthouses and beacons along the English coast. Trinity House became the predecessor to the Coast Guard and was charged with the authority and legal arbitration capability for the safety of all vessels sailing in England's territorial waters. Trinity House was the beginning of the customary practice of national control over territorial waters, which later became a precedent for international law.

[26.] Ibid, 335. In 1864, after numerous shipwrecks off Cape Spartel, Morocco a lighthouse was constructed by a consortium of fourteen nations; specifically deeming the lighthouse under the administration of the Sultan of Morocco. In 1892, a semaphore signaling station was added under a similar arrangement to the lighthouse. The addition of the signaling station required a clarification of the station's neutrality. The nations finally agreed that any one of the member nations could shut down the signal portion of the station in times of war even though the station had been designated as neutral. The navigation portion of the station, however, must be kept in operation for safety reasons even in times of war. This agreement provides legal precedent for the GPS selective availability decision; while a signal station

owned by a consortium and considered neutral can be targeted in times of war, the navigational systems were to be maintained intact for the common good.

27. R.R. Churchill and A.V. Lowe, The Law of the Sea, (Manchester, England, Manchester University Press, 1988), 67-8.

28. "Outer Space Treaty of 1967," United Nations Home Page [document on-line]; available from http://www.un.or.at/OOSA/treat/ost/osttxt.html; Internet, accessed September 12, 1999.

29. "Outer Space Treaty of 1967," United Nations Home Page [document on-line]; available from http://www.un.or.at/OOSA/treat/ost/osttxt.html; Internet, accessed September 12, 1999.

30. Ibid.

31. The author searched the following databases and was unable to find any domestic law that pertains to space-based navigation systems: U.S. House and Senate electronic archives, White House policy archives. These search sites are available on-line through the Internet at http://www.house.gov/house/searchall.htm, http://senate.gov/search/index.html, http://www.pub.whitehouse.gov/search/everything.html, and a comprehensive policy search site is at http://access.gpo.gov/congress/cong005.html.

32. "National Space Policy," White House National Science and Technology Council [document on-line]; available from http://www.whitehouse.gov/WH/EOP/OST/NSTC/html/pdd8.html; Internet, accessed September 6, 1999.

33. Ibid.

34. William J. Nix, "GPS Threat to American Forces," Marine Corps Gazette, (JAN 98): Volume 82, page 25.

35. "U.S. Global Positioning System Policy," White House Office of Science and Technology Policy [document on-line]; available from http://www.whitehouse.gov/WH/EOP/OSTP/html/gps-factsheet.html; Internet, accessed September 6,1999.

36. Scott Pace, et al "The Global Positioning System; Assessing National Policies," (Santa Monica, CA, Critical Technologies Institute, 1995), 102-108.

37. Kathleen Hickey, "A Better GPS," Traffic World, (March 22,1999): volume 257, page 37-38.

38. "Federal Radio-Navigation Plan," United States Coast Guard Navigation Center Home Page [document on-line]; available from http://www.navcen.uscg.mil/policy/frp1996/frp.pdf; Internet, accessed September 2, 1999.

39. "Vice President Gore, Transportation Secretary Pena Usher in New Era for Travel, Time Savings and Communications with Global Positioning Satellite System," Office of the

assistant Secretary for Public affairs [document on-line]; available from http://www.dot.gov/affairs/ost96/dot6296.htm; Internet, accessed September 8, 1999.

40. Ibid.

41. Regulations that provide for safe operating environments in the air or on the sea can be found on-line at the U.S. Coast Guard home page at http://www.uscg.mil/hq/g-m/regs/home.html and the Federal Aviation Administration's home page at http://www.faa.gov/publicinfo.htm.

42. "DOT and DOD Assure GPS Access for Civil Users," Office of the Assistant Secretary for Public Affairs [document on-line]; available from http://www.dot.gov/affairs/; Internet, accessed September 10, 1999. This announcement indicates that GPS satellites will now have two signals dedicated to civil use.

43. "Vice President Gore Announces New Global Positioning System Modernization Initiative," United States Coast Guard Navigation Center Home Page [document on-line]; available from http://www.navcen.uscg.mil/gps/issues/gpsmodinit.htm; Internet, accessed September 7, 1999. This document further expands the possible uses for GPS to include snowplows, earthmovers, and mining equipment. With the limitations on signal penetration, I'm not so sure that mining equipment will be able to receive the GPS signal.

44. The World Book Encyclopedia Dictionary (1963), s.v. "Moral."

45. "U.S. Global Positioning System Policy Fact Sheet," Office of Science and Technology Policy Home Page [document on-line]; available from http://www.whitehouse.gov/WH/EOP/OSTP/NSTC/html/pdd6.html; Internet, accessed September 15, 1999.

46. Scott Pace, et al "The Global Positioning System; Assessing National Policies," (Santa Monica, CA, Critical Technologies Institute, 1995), 24.

47. "Vice President Gore, Transportation Secretary Pena Usher in New Era for Travel, Time Savings and Communications with Global Positioning Satellite System," Office of the assistant Secretary for Public affairs [document on-line]; available from http://www.dot.gov/affairs/ost96/dot6296.htm; Internet, accessed September 8, 1999.

48. Scott Pace, et al "The Global Positioning System; Assessing National Policies," (Santa Monica, CA, Critical Technologies Institute, 1995), 94.

49. Ibid., 24-25.

50. "DOT and DOD Assure GPS Access for Civil Users," Office of the Assistant Secretary for Public Affairs [document on-line]; available from http://www.dot.gov/affairs/; Internet, accessed September 10, 1999.

[51.] The author researched The New York Times, The Los Angles Times, The Washington Post, and The Wall Street Journal issues contained in the archives of CARL Library starting with the Monday January 20, 1997 issue and ending with the Monday February 17, 1997 issue. Other than the informational article in the technology section of each newspaper there was no other reaction, either positive or negative to the President's announcement.

[52.] Scott Pace, et al "The Global Positioning System; Assessing National Policies," (Santa Monica, CA, Critical Technologies Institute, 1995), 16.

[53.] Robert Moorman, "Delaying the GPS Promise," Air Transport World, (SEP 93): Volume 30, page 36-42.

[54.] Scott Pace, et al "The Global Positioning System; Assessing National Policies," (Santa Monica, CA, Critical Technologies Institute, 1995), 16.

[55.] John Stanton, "Global Positioning System is an Asset Worth Protecting," National Defense, (DEC 97): Volume 82, page 28-29.

[56.] Scott Pace, et al "The Global Positioning System; Assessing National Policies," (Santa Monica, CA, Critical Technologies Institute, 1995), 17.

[57.] Vice President Al Gore's speech entitled "GPS to Provide Two New Civilian Signals," United States Coast Guard Navigation Center Home Page [document on-line]; available from http://www.navcen.uscg.mil/gps/issues/pressreleases.htm; Internet, accessed September 2, 1999.

[58.] Scott Pace, et al "The Global Positioning System; Assessing National Policies," (Santa Monica, CA, Critical Technologies Institute, 1995), 16.

[59.] Ibid., 108.

[60.] Ibid., 108.

[61.] Scott Pace, et al "A Policy Direction for the Global Positioning System; Balancing National Security and Commercial Interests," (Santa Monica, CA, Critical Technologies Institute, 1995), 1-5.

[62.] John Stanton, "Global Positioning System is an Asset Worth Protecting," National Defense, (DEC 97): Volume 82, page 28-29.

[63.] Robert Moorman, "Delaying the GPS Promise," Air Transport World, (SEP 93): Volume 30, page 38-40.

[64.] Scott Pace, et al "The Global Positioning System; Assessing National Policies," (Santa Monica, CA, Critical Technologies Institute, 1995), 16.

[65.] Ibid., 107.

66. Bob Preston, Plowshares and Power; The Military Use of Civil Space, (Washington, D.C., National Defense University Press, 1997), 259.

67. Scott Pace, et al "The Global Positioning System; Assessing National Policies," (Santa Monica, CA, Critical Technologies Institute, 1995), 107.

68. Robert Moorman, "Delaying the GPS Promise," Air Transport World, (SEP 93): Volume 30, page 38-40.

69. Ibid., 38-40.

70. Robert Moorman, "Delaying the GPS Promise," Air Transport World, (SEP 93): Volume 30, page 38-40.

71. Scott Pace, et al "The Global Positioning System; Assessing National Policies," (Santa Monica, CA, Critical Technologies Institute, 1995), 17.

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